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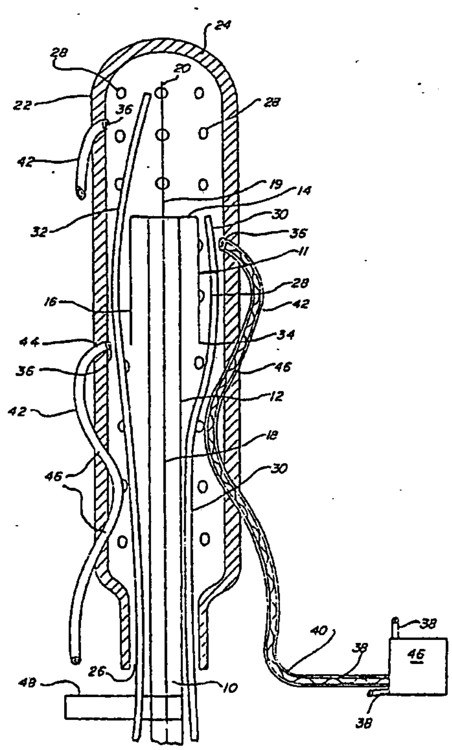
(54) Title: MICROWAVE ANTENNA SYSTEM FOR INTRACAVITARY INSERTION

(57) Abstract

A microwave antenna system for intracavitary insertion for inducing hyperthermia by microwave irradiation is provided for cancer treatment and the like. An elongated antenna (11) is adapted to laterally propagate a generally uniform field of microwaves of a wavelength of 85 to 120cm. A dielectric jacket (22) surrounds the antenna having a closed outer end (24), but open at its inner end (26). The jacket is equipped with air circulation conduits (30, 32) to cool the tissue in the immediate vicinity of the jacket.



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MICROWAVE ANTENNA SYSTEM FOR INTRACAVITARY INSERTION

TECHNICAL FIELD

Microwave treatment of cancer is currently in clinical trial. The microwaves, which are believed by many to be less harmful than X-rays and gamma rays, heat the tissue upon irradiation. Malignant tumors often turn out to be more sensitive to heat than normal tissue, so that upon prolonged heating by microwave irradiation, the tumors can be destroyed while the normal tissue is unharmed.

In the article by Petrowicz et al. entitled "Experimental Studies on the Use of Microwaves for the Localized Heat Treatment of the Prostrate: J. Microwave Power 14(2): 167-171 (1979) a newly developed microwave applicator emitting microwaves at 433.9 MHz was tested on 15 dogs. The applicator was inserted rectally, followed by 15 to 20 minutes of irradiation of the prostrate. It is, however, reported that unwanted tissue damage did occur, presumably through burning which was aggravated by the fact that microwaves of 400 MHz and higher have relatively limited capability to penetrate tissue. For example, microwaves at 433 MHz can penetrate tissue for effective heating about 4 cm. To the contrary, in accordance with this invention, penetrations of 5 to 6 cm., a 25 to 50 percent increase in depth, can be achieved.

Furthermore, the burning of adjacent tissues to the electrode is a common problem with microwave therapy which must particularly be carefully guarded against when a microwave antenna is inserted into a body cavity, since it may not be easy to determine whether the interior of the body cavity has been burned until after the fact.

In accordance with this invention, an intracavitary microwave applicator is provided having improved tissue penetration due to the use of an optimal lower frequency and longer wavelength so that, as stated before, 5 to 6 cm. of penetration may be obtained. This permits the extensive

irradiation of large tumors of the bowel and the like, so that the entire tumor area can be irradiated. For example, the bowel, esophagus, or surgically-created, temporary body apertures may be entered by the antenna of this invention and irradiated.

Furthermore, the microwave antenna system of this invention provides an improved cooling system for prevention of burning, which is critical to avoid in unseen, interior portions of the body.

DISCLOSURE OF THE INVENTION

In accordance with this invention, a microwave antenna system is provided, being adapted for intracavitary insertion for inducing hyperthermia by microwave irradiation for cancer treatment. The antenna system comprises an elongated antenna adapted to laterally propagate a generally uniform field of microwaves of a wavelength of 85 to 120 cm. A preferably flexible dielectric jacket surrounds the antenna, with the jacket having an enclosed outer end, but open at its inner end.

A plurality of air flow conduits pass through the inner end of the jacket and terminate within the jacket at different distances from the outer end. As the result of this, air entering the flow conduits is released within different portions of the jacket interior, which may preferably correspond to the "hot spots" of the microwave antenna system for optimum cooling. The released air then exits the jacket from the inner end.

It is also preferable for electronic temperature measuring means to be positioned on the jacket, with lead wires extending from the electronic temperature measuring means through the inner end of the jacket to connection with temperature readout means.

It is also desirable for impedance matching means to be provided in electrical connection with the antenna to permit matching the impedance of surrounding tissue volume when the antenna system is inserted into a body cavity.

Preferably, the microwave antenna system of this invention is operated at essentially a 100 cm. wavelength.

The use of the specified wavelengths of microwaves propagated in accordance with this invention provides not only improved effective penetration of the microwaves through tissue, so that large areas may be irradiated, but also the size of the antenna capable of effectively propagating such microwaves is substantially reduced from the corresponding sizes of the antennas of the prior art utilized for propagating microwaves of lower frequency. This is an obvious significant advantage for an antenna which is intended to be inserted into body cavities.

It is preferred for the microwave antenna system of this invention to include a coaxial cable antenna defining an inner conductor and outer cylindrical conductor. The outer conductor is folded rearwardly beginning at a point from 10 to 16 centimeters from the end of the antenna and extending from such a point in the direction away from the end of the antenna by a distance essentially equal to the spacing of the point from the end of the antenna.

The antenna is adapted to radiate microwaves of a wavelength of 85 to 120 centimeters, with the microwave antenna system being enclosed in the jacket as described above. Such an antenna structure provides relatively uniform lateral emission of microwaves with the suppression of "hot spots" in the pattern of microwave emission. Also, as can be seen, the size of the antenna is not excessive, which is an advantageous feature, coupled with the improved penetrability of microwaves of the wavelength specified above, so that an antenna which is both insertable into a body orifice, coupled with an antenna that radiates microwaves having the desirable 5 to 6 centimeters of tissue penetration, is provided.

Additionally, the cooling system of this invention preferably includes the pair of air conduits, one of which extends through the sleeve to the forward end of the antenna, and the other of which extends to said point of folding

of the outer conductor, which is a point of particularly strong microwave emission. Thus a special and selected pattern of air flow is provided to counteract excessive heating of the antenna in an optimal way.

Preferably, the wavelength of the microwaves radiated is from 90 to 110 centimeters and specifically 100 centimeters. When the wavelength emitted is essentially 100 centimeters, it is preferable for the distance of said point of folding to the end of the antenna to be essentially 12.5 centimeters, with the length of said folded portion of the outer cylindrical conductor being also 12.5 centimeters, a total of 1/4 wavelength.

It may also be desirable for a detuning sleeve to be carried by the cylindrical outer conductor, the detuning sleeve being connected to the cylindrical conductor at a position of the outer conductor. Furthermore, it is preferred for a gap of 2 to 3 centimeters to be present between the folded portion of the outer cylindrical conductor and the detuning sleeve, with the detuning sleeve extending toward the outer end of the antenna from its point of contact with the outer cylindrical conductor.

Additionally, it is preferred for the temperature sensing means to have connected lead wires that pass through an inner tubular conduit means. This tubular conduit means may in turn reside in a dielectric tube that is carried by the sleeve and communicates with the interior of said sleeve through an aperture thereof.

When desired, the inner tubular conduits containing the lead wire and the temperature sensing means may be removed from the dielectric sleeve when desired for maintenance and the like, and also may be placed into the dielectric sleeve as desired for use, with the electronic temperature sensing means being positioned generally in the aperture of the sleeve.

Typically, the electronic temperature sensing means is a microthermocouple.

BRIEF DESCRIPTION OF DRAWINGS

In the drawings, Figure 1 is a longitudinal sectional view of one embodiment of the microwave antenna system of this invention, shown partly schematically, and with portions broken away.

Figure 2 is another embodiment of the microwave antenna system of this invention, also shown partly schematically..

Figure 3 is a detailed, enlarged sectional view of the dielectric sleeve and related parts.

DESCRIPTION OF SPECIFIC EMBODIMENT

Referring to Figure 1, the microwave antenna system of this invention is adapted for insertion into a body cavity such as the colon for inducing hyperthermia by microwave irradiation for cancer treatment. Coaxial cable 10 terminates in an antenna 11 with its outer tubular conductor 12 being folded back at point 14 to define a folded-back section 16, while central conductor 18 extends outwardly. The length of the exposed end 19 of central conductor 18 from its end 20 to point of folding 14 is equal to the length of the folded portion 16, for providing optimum irradiation characteristics. It is also preferable for the distance between end 20 and point 14, as well as the length of folded portion 16, to each equal one-eight of the length of the wavelength intended for use. Specifically, when a wavelength of 100 centimeters is used, it is preferable for the above two respective distances to each be 12-1/2 centimeters.

Coaxial cable 10 and the antenna portion are surrounded by a dielectric jacket 22, which is closed at its forward end 24 and typically open at its rear end 26. Apertures 28 may be formed in jacket 22, particularly when the antenna system is intended for shallow penetration into a body aperture, for example in the mouth and upper throat. Typically when the antenna system is intended for deep penetration into the bowel or the like apertures 28 are not used.

A plurality of air flow conduits 30, 32 are provided

passing through inner end 26 of the jacket 22, and terminating within the jacket at different distances from outer end 24. As specifically shown, one air flow conduit 30 terminates adjacent to point 14, while the other conduit 32 terminates adjacent to end 20 of the antenna. Alternatively, conduit 32, or a third conduit if desired, may terminate at the rear end 34 of folded portion 16 of outer cylindrical antenna number 12. Accordingly, as air passes through conduits 30, 32, jacket 22 is continuously cooled by the action of the flowing air, with the air flowing from the respective conduits 30, 32 into the interior of jacket 22 and then out rear end 26 of the jacket. The presence of conduit 30 adjacent to point 14 provides added cooling to the "hot spot" which may be generated during microwave irradiation from this area of the antenna.

As a result of this, the tissue within which jacket 22 resides during operation remains cooled by the presence of the continuously cooled jacket, so that burning of the tissues adjacent the jacket may be avoided.

Additionally, the electronic temperature measuring means 36, typically microthermocouples, are positioned on jacket 22. Lead wires 38 extend through inner conduits 40 made of a dielectric material, so that microthermocouple 36, lead wires 38, and inner conduits 40 comprise a discrete unit. Outer conduits 42, which may be made of Teflon or the like, are attached at their ends as shown to jacket 22 and surrounding an aperture 44 in the jacket. Thus the thermocouple 36 may be threaded into outer conduit 42 and positioned at its desired place. However, when maintenance or replacement is needed, the thermocouple, inner conduit, and lead wire may be removed as a unit and/or replaced with another unit.

As shown, outer conduit 42 can be threaded through various apertures 46 in jacket 22 for firm retention thereof.

Lead wires 38 may then continue to a conventional temperature readout device for the microthermocouple 36, so that the temperatures of the various microthermocouples may be continuously monitored.

The above structure provides a convenient system for temperature monitoring of the device of this invention in which the lead wires are protected by the Teflon outer conduits 42, and yet the thermocouples and lead wires may be removed by maintenance or replacement as is required. Also, the latter structure may be preserved for future use, while jacket 22 and the enclosed antenna may be utilized only with respect to one patient and then disposed of.

Impedance matching means is provided in the form of a tuning stub 48, in communication with coaxial cable 10, to permit matching the impedance of surrounding tissue volume when the antenna system is inserted into a body cavity.

The embodiment of Figure 2 is similar to that of Figure 1, including coaxial cable 10, jacket 22, and the folded antenna portion of the outer sleeve 16a plus the projecting inner antenna portion of identical design to that of the previous embodiment. Air tubes 30a and 32a are also provided to be of equivalent function to the corresponding air tubes of the previous embodiment, along with the related structure which is also of analogous design. The same microwave frequencies may be used.

In this embodiment, jacket 22a is shown to be without perforations and thermocouples, although such may be used if desired, as previously.

Also, in accordance with this invention a detuning sleeve member 50 is provided, it being connected to outer tubular conductor 12a and extending toward folded portion 16a, being preferably of identical length to folded portion 16a.

It is preferred for the space 52 between detuning sleeve 50 and the folded tubular portions 16a to be from 2 to 3 centimeters to avoid causing the detuning sleeve to emit radiation. The function of the detuning sleeve 50 is primarily to block rear leakage of radiation, so that the radiation is concentrated in the desired areas.

Accordingly, a microwave antenna system is provided which yields the combined advantages of increased tissue

penetration, coupled with improved means for eliminating burning of adjacent tissues, and further coupled with an antenna of manageable size so that it can be effectively used for insertion into the body orifice of a patient. Antennas of lower wavelength and higher frequency exhibit substantially less penetration of tissue, which is undesirable in many circumstances. Antennas of longer wavelength do not exhibit great improvement in tissue penetrability, and at the same time such antennas must generally be larger and thus quite difficult to effectively use clinically for the penetration of body orifices.

Furthermore, a higher percentage of radiation of the particular frequency utilized in this invention is absorbed by the tumor tissues, relative to that absorbed in healthy tissues, than at the higher frequencies which have been more commonly used in tumor therapy.

Furthermore, an optimum structure for cooling and for temperature measuring is provided as well as means for reducing unwanted rearwardly emitted radiation.

The above has been offered for illustrative purposes only, and is not intended to limit the invention of this application, which is as defined in the claims below.

THAT WHICH IS CLAIMED IS:

1. A microwave antenna system adapted for intracavitary insertion for inducing hyperthermia by microwave irradiation for cancer treatment, which comprises:

an elongated antenna, adapted to laterally propagate a generally uniform field of microwaves of a wavelength of 85 to 120 cm., a dielectric jacket surrounding said antenna, said jacket having a closed outer end but open at its inner end;

a plurality of air flow conduits passing through the inner end of the jacket and terminating within said jacket at different distances from said outer end, whereby air entering said flow conduits is released within different portions of said jacket interior and then exits said jacket from the inner end.

2. The microwave antenna system of Claim 1 in which electronic temperature measuring means are positioned on said jacket, and lead wires extending from said electronic temperature measuring means to connection with temperature readout means.

3. The microwave antenna system of Claim 2 in which impedance matching means is provided in electrical connection with said antenna to permit matching the impedance of surrounding tissue volume when said antenna system is inserted into a body cavity.

4. The microwave antenna system of Claim 3 in which said wavelength is essentially 100 cm.

5. A microwave antenna system adapted for intracavitary insertion for inducing hyperthermia by microwave irradiation for cancer treatment, which comprises:

a coaxial cable antenna defining an inner conductor and an outer cylindrical conductor, said outer conductor

being folded rearwardly beginning at a point from 10 to 16 cm. from the end of said antenna and extending from said point in the direction away from said end by a distance essentially equal to the spacing of said point from the end of said antenna, said antenna being adapted to radiate microwaves of a wavelength of 85 to 120 cm., said microwave antenna system being enclosed in a jacket surrounding said antenna and having a closed outer end.

6. The microwave antenna system of Claim 5 in which the wavelength emitted is essentially 100 cm., and the distance of said point of folding to the end of said antenna is essentially 12.5 cm.

7. The microwave antenna system of Claim 6 in which said wavelength emitted is essentially 90 to 110 cm.

8. The microwave antenna system of Claim 5 in which said jacket is perforated.

9. A microwave antenna system adapted for intracavitary insertion for inducing hyperthermia by microwave irradiation for cancer treatment, which comprises:

an elongated coaxial cable antenna defining an inner conductor and outer cylindrical conductor, said outer conductor being folded rearwardly beginning at a point from 10 to 16 centimeters from the end of said antenna and extending from said point in the direction away from said end by and essentially equal to the spacing of said point from the end of said antenna, said antenna being adapted to radiate microwaves of a wavelength of 85 to 120 centimeters, said microwave antenna system being enclosed in a jacket surrounding said antenna and having a closed outer end, and a pair of air tubes passing into said outer jacket from the inner end thereof with one of said air tubes terminating at the end of said coaxial cable antenna, the other of said air tubes terminating at said point, whereby air entering said

flow conduits is released within different portions of said jacket interior and then exits said jacket from the inner end.

10. The microwave antenna system of Claim 9 in which electronic temperature measuring means are positioned on said jacket, and lead wires extending from said electronic temperature measuring means to connection with temperature readout means.

11. The microwave antenna system of Claim 10 in which said wavelength emitted is essentially 90 to 110 cm.

12. The microwave antenna system adapted for intracavitary insertion for inducing hyperthermia by microwave irradiation for cancer treatment, which comprises:

an elongated antenna, adapted to laterally propagate a generally uniform field of microwaves, a dielectric jacket surrounding said antenna having a closed outer end and an open inner end, an electronic temperature measuring means positioned on said jacket, dielectric tubes extending from said electronic temperature measuring means rearwardly of said jacket, an inner tubular member inserted within each of said dielectric tubes, said inner tubular members enclosing lead wires and communicating between said electronic temperature measuring means at one end and temperature readout means at their other ends, whereby said inner tubular means, lead wires, and electronic temperature measuring means may be installed and removed through said dielectric tubes.

13. The microwave antenna system of Claim 12 which includes an air flow conduit means passing through the inner end of the jacket and terminating within said jacket, whereby air entering said flow conduits is released in said jacket interior and then exits said jacket from the inner end.

14. The microwave antenna system of Claim 13 in which a plurality of air flow conduits pass through the end of the jacket and terminate within said jacket at different distances from said outer end, whereby air entering said air flow conduits is released within different portions of said jacket interior and then exits said jacket from the inner end.

15. The microwave antenna system adapted for intracavitary insertion by inducing hyperthermia by microwave irradiation for cancer treatment, which comprises:

a coaxial cable antenna defining an inner conductor and an outer cylindrical conductor, said outer conductor being folded rearwardly beginning at a point from 10 to 16 centimeters from the end of said antenna and extending from said point in the direction away from said end by a distance essentially equal to the spacing of said point from the end of said antenna, said antenna being adapted to radiate microwaves of a wavelength of 85 to 120 centimeters, said microwave antenna system being enclosed in a jacket surrounding said antenna and having a closed outer end, said antenna also carrying detuning sleeve means communicating with said outer conductor at a point spaced farther away from said end than the folded outer conductor, said detuning sleeve means defining a portion extending toward said folded outer conductors, but spaced at least 2 centimeters therefrom, whereby rearward leakage of microwave radiation is suppressed.

16. The microwave antenna system of Claim 15 in which said detuning sleeve means is spaced no more than 3 centimeters from the folded antenna.

17. The microwave antenna system of Claim 16 in which a plurality of air flow conduits pass through the inner end of the jacket and terminate within said jacket at different distances from said outer end, whereby air entering said

flow conduits is released in different portions of said jacket interior and then exits said jacket from the inner end.

18. The microwave antenna system of Claim 17 in which electronic temperature measuring means are positioned on said jacket, and lead wires extend from said electronic temperature measuring means to connection with temperature readout means.

19. Microwave apparatus useful for treating cancer with heat, comprising:

a source of microwave radiation;

a hollow member and conductor means delivering said microwave radiation to said hollow member to generate heat; and

a source of air and means for delivering said air to said hollow member to control the external jacket temperature.

20. Microwave apparatus as defined in Claim 19, including thermocouple means mounted on the hollow member for indicating the external temperature thereof.

21. Microwave apparatus as defined in Claim 19 in which the hollow member comprises an elongated flexible jacket having an open end and a closed end, and including means for delivering said cooling fluid into selected positions in said jacket so that the fluid is discharged through the open end from the jacket.

FIG. 1

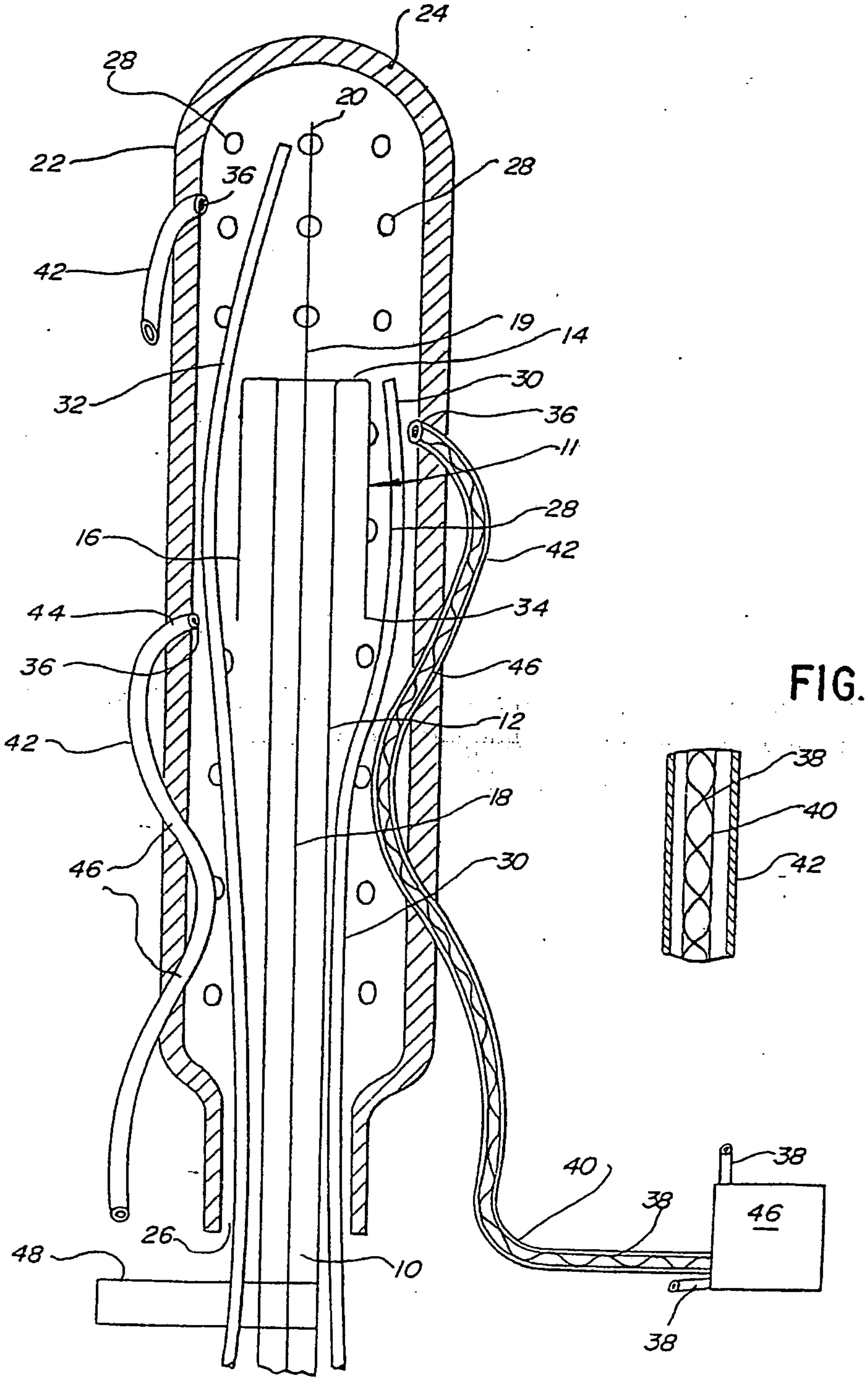
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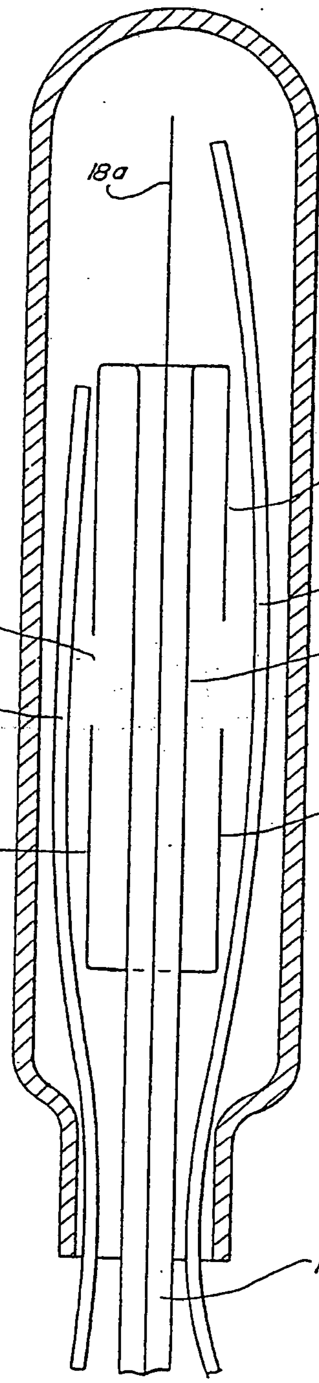
FIG. 3

FIG. 2



INTERNATIONAL SEARCH REPORT

International Application No PCT/US81/00809

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL. 3 A61N 5/02
U.S. CL. 128/804; 128/736: 128/401

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	128/804,783,784,786,736,400,401,798

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	US,A, 1,652,954 Published 13 December 1927 Pierce	1,9,13,14,17, 19
X	US,A, 4,204,549 Published 27 May 1980 Paglione	1-21
X	US,A, 4,140,130 Published 20 February 1979 Storm, III	1-3,9,13,14, 17,18
X	DE,A, 2,407,559,Published 28 August 1975 Dreyer et al.	1-21
X	DE,A, 2,815,156 Published 19 October 1978 Convert et al.	1-21
X	DE,B, 1,172,382 Published 18 June 1964, Fritz.	1,9,12
X	Proceeding of the 8th European Microwave Conference, issued September 1978 (Paris, France) Buck, "Slotted Cylinder Antenna For Selective Electromagnetic Heating Inside The Humen Body", (See pages 548-552).	1-4,9-21
X,P	Int. J. Radiation On cology Biol Phys., Vol. 6, No. 11, issued November 1980, Mendecki et al, "Microwave Applicators For Localized Hyperthermic Treatment of Cancer of the Prostate", (See pages 1583-1588)	1-21

* Special categories of cited documents: [15]

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"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
17 September 1981	24 SEP 1981
International Searching Authority [1]	**Signature of Authorized Officer** [10]
ISA/US	Lee S. Cohen